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ON SOME PHOTOGRAPHIC APPARATUS USED IN AERIAL PHOTOGRAPHY

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Introduction. The ideas which we obtain by visual examination of the form of an object, or forms of a series of objects under any given atmospheric conditions, are conditioned by our point of view. As a general rule we endeavour, with small objects, to view them from such a position that the eye is on a level with their centres—they are examined at eye level. With a series of objects arranged in space, as, for example, a landscape, the eye is below the mean height of the centres of these objects. This is the impression which is obtained, in general, amongst people as to the appearance of the surface of the earth. On the other hand, it frequently happens that we examine objects from a point of view considerably above eye level, and stretches of country are often viewed from heights, for instance, from a mountain side. In many instances photographers choose a view point from the top of a building. If the picture includes much of the foreground, a rather curious and frequently irritating impression is obtained, because we instinctively think of the object as it would appear when seen from ground level and try to fit in this mental impression of the object with what is actually portrayed in the photograph. This, I think, is the psychological reason why such photographs are generally unsatisfactory. At the most, however, the ordinary individual never sees nature except from a comparatively low altitude. It is reserved for the airman who "sits up aloft" to appreciate another aspect—the character of nature as seen vertically below or at angles relatively considerable as measured from the horizontal. The airman, it is true, may have frequently seen relief maps of portions of the earth's surface which are generally selected because they present some striking physiographical feature. Again he may have seen, looking down into cases in museums, models of St Peter's, or the Acropolis, but until he has been wafted gently through the air in

the car of a free balloon, or stood looking below him from the car of a captive kite balloon, or flown rapidly through the air in an aeroplane, he has never before had an opportunity of seeing under totally unusual conditions, the charming landscape—great buildings, the river, the street, the vignetted edge where suburb meets the country side, with all their varied colours under continual atmospheric change.

In the course of the evening I shall describe to you the optical, mechanical, and chemical means by which these fleeting impressions can be recorded and rendered useful in the service of man. Before doing this, I propose to show you a few pictures which will give you an idea as to how some familiar scenes and objects appear when viewed from above. To-night, the main bulk of my observations will be directed to the apparatus used for aerial photography when employed as a means of providing information for military purposes, but for the present we may imagine that no such thing as hostilities exist—that we are applying one of the most interesting applications of photography purely to peaceful purposes.

General Principles.

The conduct of military operations in detail with an army in the field is governed largely by a knowledge of what is being done by the opposing force, and every military commander therefore seeks to perfect, with the various means at disposal, his information as to the host arrayed against him. In times past, when operations were generally conducted by means of open warfare and both armies were continually on the move, the time-honoured methods of reconnaissance may have sufficed, but when armies have settled down to operations with fixed positions it becomes a matter of vital necessity to know the actual defences, the position of guns, and the means and the state of all the activities behind the lines by which "supply" of various kinds is being maintained. These conditions are continually changing and for the defence to be maintained or a contemplated attack to be successful, minute day to day information as to enemy conditions and activity is essential. It is not sufficient, for example, to know that there are certain trenches in a particular portion of a sector; it is necessary to know the form of the trench, its relation to other defences, the state of the ground, and what obstacles would be encountered were an attack to be made. Such information could not be given with sufficient accuracy by any of the old methods of obtaining intelligence. The entry of the aeroplane into warfare rendered it possible to furnish the Staff with the detail necessary and by use of this agency military reconnaissance gained a powerful aid.

In the early days of the war reliance was placed upon the reports of aerial observers who were trained soldiers, and who, by reason of their military knowledge, were able to provide the Staff with that information which was of value. But, however highly trained the observer may be, his powers are limited, it is impossible to make maps from the air to the extent and with the accuracy and detail which is required, and in consequence the duty of the observer would be confined to making such observations as were permitted by his powers. Psychological conditions also govern these observations—the human mind in a state of tension is not sufficiently impersonal, and if observations at times have lacked the fullness and accuracy which

was necessary, this must be held to be due frequently to the extreme difficulty of the task.

Beginnings of Aerial Photography.

Looking back on the past, it is matter for some explanation as to why an impersonal means for obtaining information like photography was not adopted at an earlier stage than was the case. Much may be explained by that attitude of conservatism which is one of the most striking features of every organisation, both civil and military. But not by this alone. The truth is that prior to the war there had been no serious attempts to make photographs from the air, even from balloons. It is quite true that photographs had been made from balloons, but, so far as I am aware, the camera did not form part of the aeronaut's normal equipment, curious as this fact may seem. Consequently, when some venturesome spirits did suggest that the camera should be used from an aeroplane for the purposes of trying to obtain information as to the enemy's positions and organisation, they met with the usual experience of those who desire to introduce innovations. It was due to the persistence of some officers in the Royal Flying Corps that the attempt was made. Although carried out with very imperfect appliances, the result of these initial efforts was such that the practice obtained a limited recognition, but it was a long time before that which eventually became so important a branch of military intelligence obtained any real or extended appreciation.

We may assume, as substantially correct, that for all practical purposes aerial photography is a product of this war, and that it arose, so far as this country is concerned, certainly from the pioneer work carried out in the Royal Flying Corps. The original efforts were first made by means of ordinary focal plane hand cameras, and it was not until the early months of 1915 that the first photograph was made from an aeroplane, above Fauquissart, by means of a camera designed for the purpose.

Forms of Apparatus Employed.

I propose this evening to give you an account of the principal forms of apparatus which have been used, but before doing so, it may perhaps be convenient if I ask your attention to the general principles underlying the construction of a photographic camera, because an aerial camera, in its simplest form, fulfils these conditions.

A photographic camera consists of an arrangement for holding a lens at a fixed distance from a sensitive plate, a receptacle for holding that plate, and some arrangement for ensuring that only the light which passes through the lens shall reach the plate. The axis of the lens, when prolonged, passes through the centre of the plate, which is at right angles to this axis. The distance between the lens and plate are fixed once and for all, being determined by the principal focal distance, or focal length, of the lens. If the conditions be fulfilled, you have what is known as a simple box camera, and all the early types of aerial cameras were of this form. Whatever departures were made from this type were mainly mechanical devices

for ensuring the automatic changing of the plates and the setting and release of the shutter—the camera itself remaining unchanged. The object being at a relatively great distance from the lens, the plate is always practically at the principal focus of the lens, and for this reason it is a fixed focus apparatus.

The Sizes of Plates.

The standard size of plate adopted in the case of all the early cameras in the English Service was 5 × 4 and remained so for a considerable length of time. Eventually 8½ × 6½ plates were used, and finally, by agreement between the Allies in 1918, 24 × 18 cm. size was adopted. The French used generally 13 × 18 cm., the enemy 9 × 12 cm. in the earlier days but eventually 13 × 18 cm., and I have seen a camera employed by the Germans for 12 × 10 in. In the Royal Naval Air Service, a few half-plate cameras were used. For a long time only plates were adopted, but the Germans employed films. Film cameras were designed by the Allies and had the war continued they would have been employed, not from choice but from necessity.

The Question of Lenses.

With regard to the lenses, the focal length selected was determined by the size of plate used. The R.F.C. and the R.N.A.S. used with the 5 × 4 plate lenses of 8¼″ *f*/4·5,—eventually these were replaced largely by 10″ of the same aperture. Lenses were used of increased focal length up to 45″ by the squadrons of the R.N.A.S. operating on the Belgian Coast. The French employed for their 24 × 18 cm. plates lenses of 1·20 metres working at *f*/6, but towards the end of the campaign the Allies' standards were 8¼, 10½, 15 and 20 inches. Excellent wide angle work of large tracts of country was done with objectives of 6″, and in some instances even 4½″ lenses were used on 5 × 4 plates. Much difference of opinion has existed at different times as to the most suitable focal length for lenses, and the differences have not always been the result of informed judgment. Practically speaking, flying height would appear to be the most important criterion, but not always so. It would seem that a certain size of image is necessary in order that the image of an object should be sufficiently large to enable the interpreter of the photograph to form a correct judgment of the nature of the subject represented, but it is not strictly correct to say that the larger of two images is necessarily the better. Given a lens that defines well, and let the photograph be free from the effects of vibration, there is no doubt that lenses of shorter focal length can be used than when the reverse is the case, and it will be all to the advantage to use the lens of shorter focal length because of the reduction of bulk and, what is very important, of weight. A modern aeroplane has to carry so much that every pound extra reduces climb and speed, also the space for movement in the machine which is very necessary. Again, photographs are taken for different purposes. In some cases, large tracts of country are required for Army operations, and for this purpose beautiful pictures have been made by means of 10½″ lenses on whole plates at from 16,000 to 18,000 feet altitude. On the other hand, for Corps work, when photographs of works in detail are wanted,

8″ to 10″ lenses were used on 5 × 4 plates at altitudes of 4000 to 6000 feet; in many cases 20″ lenses were used on 5 × 4. A low altitude does not necessarily mean great danger. In general it may be said that as the enemy defences against aircraft became improved, flying height increased. There are machine guns in the trenches which attack low-flying machines, and anti-aircraft batteries for those flying at greater altitudes and there are, in addition, enemy fighters waiting aloft always ready to pounce. Mere altitude is no protection—machines have been hit at 18,000 feet by A.A. The coastal batteries in Belgium were particularly dangerous—8″ shells are usually very trying when they burst in the vicinity of a slight structure of lath and fabric. It was universally recognised that so far as aerial work was concerned, the lot of a photographic pilot and observer in an active sector was deadly dangerous, for although the fighters which in later days always accompanied the photographic machine were a protection against enemy scouts, both were recipients of the attention of the A.A. batteries. It must also be remembered that the photographic observer had, as well as attending to his camera, to fight his own gun, hence you will see that, as the days went on and the enemy defences became more complete, the call for the automatic camera became insistent.

The 5 × 4 photographs were enlarged to 8½ × 6½ or to 10 × 8. You will understand that with the best of skill and care, when the lenses were not good the final pictures showed some loss, and consequently when large direct pictures came into use, made by means of improved lenses, there was a constant demand for more. The method of producing prints by enlargement has certain advantages. Experience has shown, however, that *under the conditions which obtained* large direct pictures were better than enlargements from small negatives.

On the subject of lenses perhaps a few words, spoken from a purely practical point of view, may be of interest to members. When aerial photography came into being, there was at once a strong demand for lenses of large aperture, and of those engaged in the work, after exhausting the supply of new instruments, some had the task of ransacking the second-hand dealers' shops. However galling it may be to our national pride, it remains a fact that the best lenses of large aperture were not made in this country and the number of enemy-made lenses which were available was a general proof of that truth. We used all the home-made lenses that we could, and soon the leading opticians were hard put to to supply our wants. The necessary glass was not made in this country and the stocks were soon exhausted. The main source of suitable glass was France, and you will readily understand how difficult the position became, if you will remember the enormous demand for optical instruments. The numerous agencies at work endeavoured to make good the deficiency in this country, but a delicate industry is not organised so quickly as one could desire. It was the business of the Service to help all it could, and I think I can say that it did this, and the British opticians, once the material was forthcoming, gave us their best efforts. Those who have seen the results of these efforts, and who are able to judge, know how splendidly they accomplished their task. Long before the cessation of hostilities we were, in this country, not only making lenses of British-made glass sufficient for our own needs, but we were helping the Allies

as well. To-day we can make in this country lenses of certain important types from start to finish superior to their analogues produced by enemy countries or by any other country. I think this may justly be regarded as one of the triumphs of British industry during the war.

Some Optical Considerations respecting New Lenses.

In the early days of the War the lenses used were generally those which had been made and corrected to cover a plate larger than they were actually required to cover when used for our purposes. The result of this was that at the edge of the plate, in our case a 5×4 using an 8·25 lens, the correction for astigmatism was at its worst, and this generally applies to the best anastigmatic lenses corrected for angles of 56 to 58 degrees. In lenses where there exist good elements for correction it appeared that it would be possible to effect improvements by correcting the lens so that the best image would be obtained from centre to margin with, say, an 8·25 to 8·5 lens on a 5×4 and similarly with other lenses for the larger sized plates.

This principle was adopted with the Airo lenses of Ross which are derived from the Xpres lenses and are known as the Airo Xpres. The Xpres is a five lens system consisting of two uncemented elements at the front, a plano-convex for the anterior and a plano-concave for the posterior with the plane surfaces in juxtaposition, and a cemented combination consisting of three elements, a plano-concave, a meniscus, and a double convex. The Airo Xpres is a modification of this—the arrangement of the lenses being the same. The Airo Xpres has been corrected for a much smaller angle than has the ordinary Xpres, actually 36 degrees against 56 degrees, with the result that there has been a considerable reduction in the astigmatical aberration in the intermediate zones of the plate. It is known that the correction for coma or the unsymmetrical aberration of oblique pencils, becomes increasingly worse with a growth in the covering angle. The image which is registered in the corners of the plates is composed of a good anastigmatically correct image and one corrected in a less good manner for coma. In the Airo lens there has been made the best possible correction for coma under the circumstances. Incidentally it may be mentioned that Harting amongst others has stated that lenses well corrected for the sine condition are free from coma. I am informed by Messrs Ross & Co. that this has not been the experience of the firm in its optical work, and that they do not agree that it holds good with photographic lenses of large aperture and covering power. They find that the zonal aberration of oblique pencils follows closely the aberration of central pencils and that a better lens can be made as regards correction for coma with lenses showing small zonal aberration for central pencils.

The difficulty in obtaining an adequate supply of suitable glass for lens making has been referred to at an earlier stage of this paper. In response to a call from the Service for a lens which could be quickly made from material obtainable in this country, Messrs Ross constructed the $f/6$ Airo lens. This type is made of four

dissimilar elements, two kinds of glass only being employed, a light flint and a dense barium crown, and the performance of this lens is one of which the firm may be justly proud.

Photographs from test negatives showing the performance of the new lenses together with that of German lenses of the same type and as near as possible the same focal distance are placed upon the table so that members may form their own judgment as to the progress which has been made.

The Aviar lens made by Messrs Taylor, Taylor, and Hobson consists of four separated elements, the outer pair being convex and the inner pair concave. This is in fact the essence of the Cooke lens and is as sketched by Mr H. Dennis Taylor in one of the earliest of the Cooke patents. The early models constructed in this pattern were not, however, an improvement on Mr Taylor's simple Triplet system as they showed large zonal aberration and curvature. Investigation later, however, showed that with the best possible distribution of curvatures the zonal aberration could be considerably reduced.

It has been found impracticable to make the lens so that the two halves could be used as separate combinations, for the aim in construction has been to obtain a lens which would function satisfactorily as a whole. The unsymmetrical form has been found to be the most favourable. Both halves have a positive focal distance, the focal distance of the front being usually longer than that of the back. The separated combination could be used, but their employment as such would necessitate a reduction of aperture to $f/16$ or $f/22$.

The method of distributing the curvatures covered by the Aviar patents is, I am informed, capable of being utilised for a wide variety of constructions ranging from a lens of considerable focal distance, $f/4{\cdot}5$ giving a centre like the Petzval objective but with an anastigmatically flat field of 35 degrees extent, to a lens of short focal distance $f/4{\cdot}5$ covering a field of 52 degrees. The performance of the Aviar lens was admirable.

I am not able to give optical details of the other new lenses, but the makers may announce them at some future date (see Appendix 1).

Mechanical Means for Control of Exposure.

It is perhaps convenient, whilst discussing principles, to consider briefly the question of the mechanical means by which the necessarily short exposure of the plate in the camera is secured. Exposures varied in the order of about 1/100th to 1/150th of a second. This period was not alone necessary owing to the motion of translation of the machine, which many have assumed, but was determined as well by secondary movements which introduced serious difficulties. To commence with, the movement of a machine in the air is not a movement of pure translation. Machines are liable to gyratory motion of different orders of magnitude, and there is always the fact of vibration to contend with, which varies with different machines, and is often moreover periodic. If you consider the case of a hand-held camera, by means of which the early work was done (during which period the greatest of our difficulties occurred), there are up and down movements—which do

not matter much—to and fro movements—which are objectionable, but the most serious trouble arose from a rotary movement round a vertical axis and round a horizontal axis, and of these two the latter causes the most difficulty.

There are two methods of causing eclipse, the between-lens shutter—we put out of consideration the shutter in front of or behind the lens—and the moving slit in front of the plate, the so-called "focal plane shutter." In considering which is the better, you may make, if you choose, a theoretical assumption, for the purposes of argument, that there is existing a between-lens shutter of unit efficiency which is capable of giving an exposure of a sufficiently brief duration. If this assumption be correct, then to my mind there is no question which is the better form—one would choose the between-lens device. Unfortunately, no such shutter exists. If we place 0·6 as the highest efficiency we still suffer a serious drawback, but even with this the difficulty is not surmounted, for no large shutter exists capable of giving so short an exposure as 1/100th of a second, the marked values notwithstanding. With very small shutters such as would not answer our purpose it is just possible that one might be found capable of giving the time stated, but certainly none has been found suitable for use with 8¼" to 10" lenses of $f/4{\cdot}5$ aperture, laying aside the inconvenience of the large bulk. Recourse must therefore be made to the focal plane type. The focal plane shutter has long held pride of place, and the comfortable assumption is frequently made that it is a perfect device. This is unfortunately only an assumption which is not borne out by proper theoretical investigation or by practical experience. To commence with, the slit does not move in the plane of the plate, and judging by the practice of many makers of cameras, one sometimes feels that the necessity for even an approximation to this necessary condition had been completely overlooked. Further than this, the motion of the blind is never uniform and the shutter always introduces an element of distortion which in aerial photographs intended for mapping is serious. Where there is periodic vibration it has very often happened that the periods of maximum effect come during exposure, with the result that there are marked bands of movement. It has been our constant endeavour to introduce improvements and to a certain extent we have been successful, but we have been far from satisfied. The most important thing is to secure a high blind velocity so that one can work with a wide slit, which in itself is the best means of overcoming distortion, but high blind velocities are mechanically difficult to secure, and springs which function well on the ground frequently cause trouble in cold weather when working at very high altitudes. My own view is that the tension of springs should be set once and for all—it is entirely inimical to constancy to vary tension. Another trouble lies in the fact that there is no ready means by which, in a series of cameras, one can ensure uniformity in spring tension, and we have been driven very largely to depend on a system of trial and error—certainly far from a desirable state of things. Bound up with the question of freedom from vibration, especially with hand-held cameras, is the method of release of the shutter. Few people, outside the Services, have any idea of the amount of attention which has been given, and

necessarily given, to this apparently small but actually highly important detail. In the early days the slit width was varied by means of the sliding cord, but latterly self-capping shutters were employed, and here the difficulty was to maintain constancy of aperture—a particularly difficult task with mechanically worked cameras. The Germans employed triple fixed slits, a method which avoids some difficulties, and the Americans employed single slit shutters. Always, I regret to say, the Germans made better shutters than our own; their greatest skill was put into this feature. When the non-self-capping form was employed, means had to be taken to prevent exposure of the plate during changing and this introduced a complication. The German shutters were always removable—a plan which had advantages. The only part of the ordinary non-automatic camera likely to get out of order is the shutter. In such an event it is only necessary to withdraw this portion and insert another from the spares. This method was adopted by the British Service later, but only for the automatic cameras; any extension of this principle to the non-automatic cameras would have necessitated re-design of the apparatus. The safety device with German shutters consisted of two flaps, operating in front of the blind and forming part of the shutter mounting, which were raised as the first action, when the shutter release lever was depressed. Our safety device, on the other hand, was a lens flap, lifted in the same way, which was in land cameras behind the lens, but in cameras for sea operations in front of the lens, where it served the additional and very important function of protecting the lens from sea water spray. In the first aerial camera the trouble of accidental exposure by winding up the blind when the shutter was withdrawn was avoided by means of an arresting peg which fitted into the shutter of the Mackenzie-Wishart slide, and prevented it from being withdrawn until the blind was wound up. So far as I have had the opportunity of examining enemy cameras, no use of the self-capping shutter has been found. In certain enemy apparatus, as in the film type shown on the table, a single slit oscillating to and fro was employed.

On Plate Holders.

With respect to the receptacle for holding the sensitive plate, the British Service employed at the start the Mackenzie-Wishart system, and of these envelopes tens of thousands were used. This system has many advantages, the chief being the compactness and small weight of the plate holder. The main drawbacks are the liability, inherent in the system, to damage the plates through careless handling of the flexible envelope and the difficulty of securing the accurate register particularly necessary with lenses of large aperture. The fault so often found by users of this system in ordinary photography, viz., scratches, was avoided, and can always be avoided, by cleanliness and attention to the velvet bands which act as light traps in the draw-out portion. The envelope holder, or slide, was held permanently in the back of the camera by means of a screw. Some difficulty is found in inserting the envelope owing to the high wind pressure when flying, particularly when the camera was employed fixed to the exterior of the machine, and oftentimes the

envelope would be lost by inexperienced or inattentive observers, or the shutter of the holder would be torn bodily away, a trouble which was to a certain extent minimised by making the shutters very strong. Ordinary dark slides are very unsatisfactory although they have been employed, the chief drawback being the weight and bulk, and moreover there is very great difficulty in avoiding the loss of the shutters (which are easily blown off) at the moment of withdrawal in the air current of high velocity to which the apparatus is subjected. The French Service employed hand actuated changing boxes and we ourselves have had changing boxes made though they never came into general use. The German Service employed almost wholly, for plates, changing boxes of the Ernemann type, an example of which is shown. These boxes were very well made and generally by the Ica Company of Dresden. The Germans quickly found out that no changing box of this type is reliable if employed for a greater number of plates than six. A form of changing box we employed with success in the Service for a considerable number of plates is shown in conjunction with the camera on the table. This is of the duplex type, the plates as usual being held in steel sheaths, upon which, I may say, a great deal of the success depends. The plates are held in a magazine fixed to the camera, the plate after exposure being drawn out of position by means of a rake, a fresh plate dropping automatically into position whilst the exposed plate drops into a box. This form was used for whole plates by the Naval Unit operating on the Belgian Coast, as many as from 24–36 plates being used at one time. The French Service here and there used this changer; I saw at Fismes in 1916 a box of this type, which had been made in the workshops of the Squadron, for 18 plates, which had been quite successfully used. It is only right to say that this device requires the most careful attention, and even with this attention jambs do occur which may put the whole magazine out of action. Changing boxes of whatever form are scarcely reliable even in the hands of skilled users. All forms of changing boxes go wrong even when used on the ground, and the conditions in the air are much more trying, for the user has much to contend with. The unskilled photographer generally attacks a changer with ferocity when he finds that it fails to act, but this is always an unwise procedure. To my mind there is no half-way house between a hand-worked camera with slides and an automatic device. It is essential that the observer's attention be not too much occupied, for it must always be remembered that he frequently has to abandon his camera and stand to his gun. The most successful form of slide is the double slide with "curtain" shutters and of these large numbers have been employed by the French, the Italians, and ourselves. There is no risk of losing the shutter and it is quite easy to secure good register; moreover, they are compact in form and very light. Originally made and used in France, they have been made in England and Italy and I am sure that experience has shown the English make on the whole to be the best. There is of course nothing new in the curtain form of shutter; it was employed years ago in photographic construction—I remember that thirty years ago it was employed by George Hare in his plate changing boxes—and practically all the best modern darkslides for photo-mechanical work use the flexible or curtain shutter.

The Correction Filters.

The correction filters employed with orthochromatic and panchromatic plates were the *K* series of Wratten. These were mounted in optically worked flats which were a source of considerable expense, particularly with large lenses. For a long time the Service employed, quite successfully, the gelatine films alone, placed between the combinations. When carefully used they were quite satisfactory, the main precaution to be observed being that the film fitted loosely on the lens diaphragm ring so that no buckling took place, for when there was a departure from planarity the definition given by the lens was impaired. It was found, however, that with lenses of long focal distance a diminution of definition did frequently occur, even with all precautions, and for this reason flats were generally employed. In addition to yellow correction filters, when the colour used was generally the well-known "Filter Yellow *K*," filters have been used for absorbing ultra-violet radiations, in which the agent has been a colourless substance, aesculine, naphthol disulphonic acid, or even quinine sulphate. Of course, the best is aesculine, but this body is not stable and when kept in balsamed filters discolours even in the dark. The Germans sought to overcome this difficulty by using cells containing the aesculine in a jelly form. The idea of using a colourless substance is to secure that the ultra-violet is absorbed without reducing the visible light. This is an example of an overdue deference to a theoretical principle, for to be accurate, one can absorb ultra-violet by means of Filter Yellow *K* before the visible radiations at the other end of the spectrum are reduced to any extent that matters. For spectrum photography, particularly in the laboratory, a solution of aesculine is a very convenient agent to use, but since it is not stable in a film and for the other reason stated, I think its employment is to be deprecated. The only advantage it would have would be if it became necessary to use, as blue absorbent, a yellow colour like tartrazine, whose absorption for ultra-violet is imperfect. The aesculine element would tend to make up for the deficient property of the tartrazine. Similarly that would be, to my mind, the only justification for using the other two agents specified, quinine sulphate and naphthol disulphonic acid.

The Dry Plates in Use.

A few observations with respect to dry plates may not be without interest. Whenever this question was raised by enquirers, the impression in their minds always appeared to me to be that plates of the highest "rapidity" were necessary. At first sight this would seem to be quite reasonable, but a little consideration will show that "speed" is not the only determining factor. If the "constants" of dry plates be examined, one of those constants which shows, with different types of plate, considerable differences is the "maximum development factor" of Hurter and Driffield, by which is meant the greatest density which the plate is capable of yielding on development. A plate of high "speed" will often show a very low development factor as compared with a plate of lower "speed." The

effect of this is very marked when plates have received very short exposures on subjects of short range of light and shade, such as obtains with many subjects as photographed from the air. It is of no advantage to use a plate of high "speed" if it will not give, with the particular subject and conditions of exposure, sufficient printing density on development—plates of relatively low "speed" if possessed of high development were often found to be more satisfactory in use. It was this neglect of technical principles which often caused aerial photographers to impute special virtues to particular plates for aerial photography. Really there was no such virtue save and except that which was due to the property stated, which is a general property of value for all kinds of negative making where brief exposures on short "range" subjects are necessary.

Panchromatic or Orthochromatic Plates.

As to whether or not orthochromatic or panchromatic plates are "essential" or "desirable," I should prefer to separate the two things. Desirable, yes, generally; essential, not always. It may be stated that many of the features to be portrayed were well defined and perfectly distinct; a trench system, for example, on a bright day could be quite well shown with an ordinary plate; in certain geological formation —chalky soil—particularly so. On the other hand a modern defensive system does not consist of trenches alone; there is a maze of features regarding which the Intelligence Branch calls for information. Moreover, the art of camouflage, as time went on, became highly developed, and for these portrayals undoubtedly colour sensitive plates became necessary. Gradually, the use of panchromatic plates became almost universal. So far as I have been able to observe, no system of camouflage ever deceived the Intelligence Branch when it was aided by the photographic observer. The employment of panchromatic plates was essential not only for good colour translation into monochrome, but in the weak yellow light of evening and of Winter time it became requisite, otherwise the rendering would be so poor from under exposure as to be valueless. The panchromatic plate was therefore a plate of higher "speed" than the ordinary plate obtainable suitable for the purpose—a most important item. It must not be forgotten that with the "ordinary" plate it is only the small portion of blue in the reflected white light which affects the plate, and with low white intensity this might be so small as to have no effect at all. Further than this, it must be borne in mind that we have to contend with the scattering of blue and ultra-violet by the small particles of water dust in the atmosphere—the invisible or only partially visible haze. To avoid the effect of this, which means reduction of contrast—and the contrast in aerial subjects is generally small—it is necessary to employ absorption filters which reduce the blue intensity, and under such circumstances an orthochromatic or panchromatic plate must be employed. During latter days the British colour sensitive plates became very fine indeed, owing to the efforts of Sir W. J. Pope in producing colour stuffs suitable as sensitisers, and a whole-souled devotion to the subject on the part of some of the leading British dry plate makers who responded most willingly to our many requests.

The German Plates.

A word as to enemy plates. It has not been easy to secure for examination plates used by the enemy, for of those which have been captured most had been exposed to light before they reached our hands. A few, however, were capable of being examined. The most important characteristic was their sensitiveness to green, and by the spectral record one is driven to the conclusion that the colour stuff used in sensitising was "erythrosine," which is the agent generally employed for the production of the ordinary orthochromatic plates. In some cases the so-called "non-filter" or "self-screen" plate was used, that is to say, the film was stained with a yellow colour stuff in addition to the erythrosine. This is a highly questionable principle in practice because of the low efficiency. For the same correction it is necessary to load the plate so much with yellow colour stuff that the necessary exposure is prolonged far more than it would be for the same amount of correction using a colour filter. The plates present no feature of moment and so far as we could judge from the samples at our disposal they were not so good as, or at any rate no better than, those employed in the British Service. There is no occasion for surprise in this, for I think it will be generally admitted that the manufacture of photographic dry plates is essentially a British industry and that in this respect our manufacturers hold pride of place. Recently, a few plates from a batch captured in the East were examined and these were found to have red sensitiveness, but of an order quite inferior to those even with the least red sensitiveness used by ourselves. Actually, the colour ratios expressed as the relative exposure for equal effect were:

Blue	Green	Red
1	3·3	2

The Fixing of Lenses to Cameras, and on Finders.

A feature of some importance is the method of fixing lenses to cameras so that they shall be accurately placed with the node of emission at the correct distance. I may say at the outset that after a little experience we found that it was quite necessary that this work should be done by the Service. The method finally adopted was to make a split flange with three screws placed at 120 degrees. When the flange was fixed in the camera front, which in large and finally in small cameras was of metal, the lens was screwed into place, the distances having been so arranged that the image of a sufficiently distant object was practically sharp. A collimator was then used and the image focussed by rotating the lens in the flange. When sharp, the three screws were tightened so that the lens remained fixed. In some instances, with very heavy lenses, the male thread was placed on the mount so that the focussed lens was supported about its mechanical centre—a very great advantage (Figs. 1 and 2).

Before dealing in detail with cameras, I wish to say a little about another item of the equipment, important in itself, to which much attention has been given, viz.,

"finders." The type of finder first used on aerial cameras by ourselves was the well-known bi-concave lens. This was used in rectangular form about $2\frac{1}{4}'' \times 2''$ clear aperture. They were not popular, largely, I think, because they were not

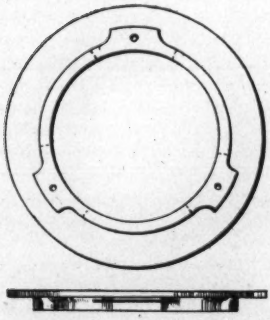


Fig. 1. This figure shows the form of the locking flange which was finally adopted.

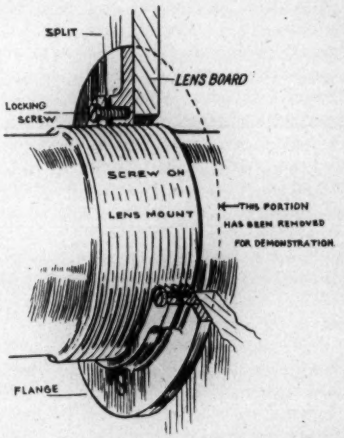


Fig. 2. The method adopted for holding very heavy lenses on the R.N.A.S. "long focus" cameras where a thread was spun on the centre of the mount of the lens so that it could be supported in its flange about its mechanical centre.

used merely for the purpose of centering the object, when they are satisfactory, but because they were employed to show the whole area portrayed, when, under the conditions of their employment, they were defective. Afterwards, there were used small tubular finders with cross wires, which could only be employed for centering. A form of finder used was the bomb sight of double concave form and of large aperture, say 6"–8", in the floor of the cockpit. But finally there came to be adopted the large open frame with cross wires and a sight, and these were quite satisfactory.

The Divisions of Aerial Photography.

Aerial photography divided itself into three distinct branches, vertical, oblique, and stereoscopic in both branches. In vertical photography the axis of the lens is vertical and the object is directly underneath the camera. This is by far the largest branch and is necessary; for example, for the correct portrayal of trench formations in plan, and is required for all subjects for which plans are necessary. Later,

when the operations of "tanks" became so important, and when information as to the general formation of the ground was in question, oblique photography was practised, and for a long time both went hand in hand, it being frequently necessary to secure both oblique and vertical photographs of the same area. Both can be done by means of the hand-held camera, but for oblique work when the camera was fixed it was so placed in the machine that the necessary angle was maintained. When either vertical or oblique photographs were required for stereoscopic purposes, two cameras were mounted side by side, the necessary relief being produced by making the exposures at a slight interval of time, which is equivalent, as the platform—the machine—is moving, to a change in position. Two cameras were necessary as with one camera a change of plate could not be effected sufficiently quickly. When automatic cameras were adopted this was no longer necessary. When automatic cameras came into use, these having to be vertical, a prism was fixed on the lens. Latterly, on account of the high cost of glass and the difficulty in securing it in blocks, plane parallel mirrors, silvered on the back, were used with perfect success, despite prognostications, due to imperfect understanding of the optical conditions, that they would be a failure. I may say that prior to the employment of these mirrors, silvered surface mirrors were tried, but they were found not only by ourselves but by other Services to be entirely unsuitable. The silvered surface mirror requires happier conditions for success than is possible in the field. In Naval aerial photography the work was generally oblique, save and except when photographs of coast line were being made. In consequence, when fixed cameras came to be employed, the machines were provided with fittings so arranged that the camera could be readily removed. In seaplanes and airships a form of fitting was used which would permit of the camera being used almost vertically or at an oblique angle—a very convenient thing. Automatic cameras were little used for sea work; largely, aerial photography was employed at sea for recording movements of ships under convoy—a most valuable aid to observation of the Admiralty's rules—for recording suspicious shipping and for showing the action of bombing of submarines. As there was a very great deal of experimental work done in connection with Naval operations, photography was largely used for record purposes from the air and on the ground.

The Cameras and their Design.

Turning to actual apparatus used, the first aerial camera employed by the R.F.C., the "A" type, was designed by officers of the Corps and manufactured by the Thornton-Pickard Manufacturing Co. which assisted in the details of the design. This camera consisted of a very simple brass bound conical box with a recessed wooden front to which the lens was fixed, the extension of the camera body acting as a mechanical protection and as a shade for the lens. The back of the camera was the shutter frame into which the envelope holder for the *M/W* envelopes were fitted. The shutter was of the focal plane type, with adjustable slit, the distance being maintained by the well-known cord

and clip. The important feature of this shutter lies in the arrangement adopted to prevent the shutter being withdrawn until the blind was wound up. To effect this, the shutter winding wheel is normally not in mesh. On pushing in the shutter of the envelope holder a peg jumps out of a cavity in the framework and enters a depression in the shutter, which cannot now be withdrawn until the blind is fully wound up. To effect this, the winding wheel is pushed home and then engages the gear, the winding wheel is turned and when the blind is fully wound up the peg holding the shutter of the plate holder falls out of the depression and the shutter can be withdrawn. This extremely simple device, easy in action and inexpensive, was quite effective. The release of the shutter was made by means of a two-way lever conveniently placed at the right-hand side. The camera was held by means of straps which could be adjusted, or by brass handles. As the apparatus had to

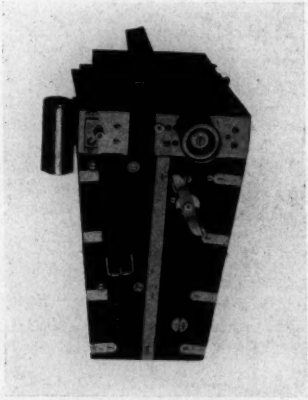


Fig. 3. The "A" type camera. Designed by the Royal Flying Corps. This was the first British camera specially designed for the work of aerial negative making.

be able to stand rough usage, every part was made very strong, and as the observer generally had to work in thick gloves, because of low temperature, the winding handle, catches and release were made large in size, far larger than would have been necessary had the apparatus been meant to be used on the ground. This camera was operated over the side of the machine for vertical or oblique work, and for vertical work, when practicable, through an aperture in the floor of the machine. The *M/W* envelopes were held in boxes fixed to the side of the machine (Fig. 3).

As you will readily understand there are serious objections to the use of wood for camera construction, principally owing to the way in which it is influenced by

atmospheric conditions. In the early days very great trouble was given in this respect, particularly with large cameras of the "A" type, which would vary from day to day, and as a result experiments were made by the different Services. In France, cameras were built out of sheet aluminium by several makers, for lenses from 25 cm. for 13 × 18 cm. plates (Fig. 4) up to 1·20 metres for 24 × 18 cm. plates, and these were most successfully used. At Dunkirk, in the R.N.A.S. workshops attached to the Aircraft Repair Depot, cameras of similar type for whole plates were made for lenses up to 40" focal distance and used with considerable success (Fig. 5). In England, cameras were made for the R.N.A.S. by different makers for whole plates on another method. The plan underlying their construction was to reduce to a minimum the possibility of alterations under varying conditions of temperature and moisture. To meet this, the idea was evolved of making a framework of four longitudinal members securely fixed at the top and bottom to stout aluminium castings. On the lens end casting there was fixed a wooden—but later metal—lens board. Upon the other end was mounted the shutter complete in its own framework, this shutter being attached at the four corners by means of screws running a considerable distance into the four longitudinal members. These members were constructed of the best seasoned mahogany that could be obtained. The strips were slit into three and reversed, being then glued together and afterwards the whole bar was well treated with paraffin wax. A sample bar was submitted to test at the National Physical Laboratory and it was found to be practically constant as regards expansion and contraction under the extremes to which it was likely to be subjected. The sides of the framework were then plated with duralumin 1/16"

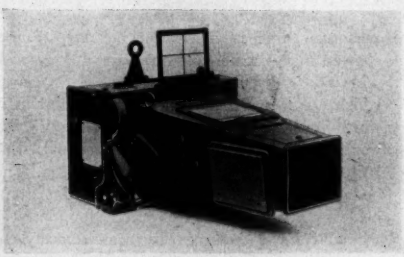


Fig. 4. The French 25 cm. camera for aerial work. This was one of the most important of the early French cameras. Fitted with self-capping shutter. Size of plate 13 by 18 cm.

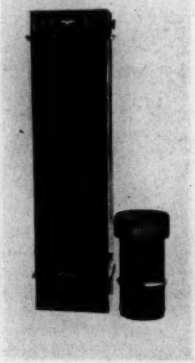


Fig. 5. An aluminium camera for a lens of 40 inches focal distance constructed in the workshops of the Aircraft Depôt, Dunkirk. This camera was very successfully employed for much work of an important character in the early days of the War.

thick. Now, if these plates were fixed, any expansion or contraction would exercise a pull on the framework and thus tend to destroy the accuracy of the lens setting at the particular time. To overcome this, the plates were fixed in grooves running the length of the members, so that if they did alter they were free to move. As a matter of fact, when the first camera was completed, it was placed in a cold storage chamber, the temperature of which was considerably below zero; the fiducial points were marked at the ends. The camera was then placed for a time in bright sunlight so that the plates had a chance to expand and the distance was again measured. The expansion was a negligible amount, but at any rate what did occur was much less than allowed for in the grooves. This form of construction was adopted for a considerable number of cameras with success (Fig. 6). Eventually owing to the cost and the difficulty in obtaining duralumin, aluminium was employed, this being carefully painted for protection. In Germany, cameras for 50 cm. lenses were made originally of first class mahogany, but as time went on the captures showed that common baywood was being used. The wooden bodies were covered with canvas which was then painted with enamel paint. It is worthy of note that the Germans seldom, if ever, wasted any workmanship on non-essentials, this attitude being more marked as time went on. The body of a camera captured on the Austrian front, made by Zeiss for a lens of 70 cm. for plates of 13 × 18 cm., was well made by means of acetylene welded sheet iron, the exterior of this body being then painted with enamel which was sprayed, while in a tacky condition, with powdered cork, allowed to dry, and then re-painted. In Austria cameras were made by building up on a veneer sheet covering a mandril, a cone consisting of strips of cane, the direction of winding being at right angles to the major dimension of the cone—to the axis of the lens—and then covering this with canvas which was afterwards painted.

Fig. 6. One of the many cameras constructed for the R.N.A.S. with the longitudinal members of mahogany. This camera is for whole plates and is fitted with a self-capping shutter. Lens 20 in. Curtain dark slides were used.

In England, 5 × 4 and ½-plate cameras were built for the R.N.A.S. wholly from sheet aluminium with the addition of castings, save and except for the shutter frame which was of wood. Further a 5 × 4 camera was made, of which a very large number were constructed, in which the whole of the body and shutter framework was an aluminium casting. This camera (the original of which is shown on the table) was largely used for oblique work in France, and in pairs for oblique stereoscopic work. It will be observed that the pistol grip type form of handle was adopted, and it was known as the Pistol Grip type in the R.N.A.S., and, when taken over, as the "P" type by the R.F.C. (Fig. 7).

The last cameras designed for Naval photography were a still further departure. The bodies consisted of spun aluminium cones, the lens being supported on a spun metal front. At the plate end the cone was turned over to form a flat and on this was fixed an aluminium sheet to which the shutter frame was attached. This

Fig. 7. The R.N.A.S. Pistol Grip camera. This camera was designed by the R.N.A.S. for 5 × 4 plates and was fitted with a self-capping shutter and used with Mackenzie-Wishart slide and envelopes. The body consisted of aluminium castings—one for the cone and the other for the shutter box.

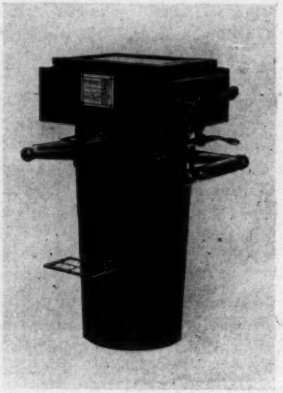


Fig. 8. The R.N.A.S. Type 18 camera. This camera was made with a spun aluminium body for 5 × 4 plates and was fitted with a self-capping focal plane shutter. This apparatus was principally used on the work of the Naval patrols.

camera, known as Type 18, was the lightest aircraft camera made. It was for $8\frac{1}{4}''$ and $10\frac{1}{2}''$ lenses and was used either hand-held or fixed in a fitting in the machine. A lighter form for 6″ lenses, which was the smallest aircraft camera produced, is shown in its various developments, including the last, when it partook of the nature of a semi-automatic film camera with fixed slit in the shutter, in which one movement changed the film and set the shutter. In all these cameras very particular attention was paid to the form and position of the handles and to the release. The shutters were of the non-self-capping type, which necessitated protecting caps on the lenses Since the camera was for sea work, these caps were fixed in front of the objective (Fig. 8).

The necessity for standardisation of bodies, which moreover could be quickly and cheaply made, led the Photographic Section with the Expeditionary Force in France to design a new body for whole plates. This was a plain cone of sheet

aluminium, which was acetylene welded at the seam, strengthening bands of brass sheet being introduced at the two ends. This formed the standard body. If a 20″ lens was to be used the whole cone was employed. If, on the other hand, a camera was wanted for wide-angle work, say for 10½″ lens, the cone was cut down, the same shutter and plate holder being used in both cases. This led to great simplification and was quite successful. Any alteration to be made would be in the plate changing mechanism, but it was required that there should be no alteration in the cone or body. One great advantage of this settlement was that the standard fittings in the machine would not be altered to take new cameras. It will readily be understood that in a Service where there are continual alterations and improvements in apparatus and methods, in so far as may be possible the new articles should work with the old, otherwise there is great delay. Two systems have generally to be worked at once in all the progressions and improvements, the "spares" tend to accumulate at a rapid pace, and so unless there is some reasonable amount of inter-changeability, the whole question of equipment becomes unreasonably complicated.

The Hand-held Camera.

I have already referred to the disadvantages of the hand-held camera. The distortions due to axial movements of the apparatus made it very difficult to use the photographs for the purpose of mapping; not only so, but there was in addition the ever present possibility of vibration, which led to a want of sharpness in the pictures. These defects, of course, showed much less in the photographs made by skilful observers, but in a large Service it is necessary to provide apparatus and conditions which will produce satisfactory results when there is exhibited only the minimum amount of human skill, for it is not to be expected (or at any rate it does not happen) that skill will always be available. To provide means by which the effects of these disturbances were minimised the natural idea would be to provide a fitting for the camera by which the instrument would be securely held. It was decided to adopt a rigid fitting, that is, the camera was to be securely fixed to the machine, and in the first effort the camera was placed outside the aeroplane in a convenient position for the observer's use. It might be thought that though in this position the axial movements would be avoided, the movements due to vibration would be much more liable to show—that, in other words, the body, when the camera was held in the hand, had acted as a vibration damper. This is probably to some extent correct. Experience showed very soon that a great improvement resulted from the use of the simple rigid fitting, but many difficulties remained. The vibration varied in different machines and in different places in the machine so that the effect would vary according to the position of the camera, and with different engines. With rotary engines, the vibration trouble was more accentuated than with engines that were fixed. It therefore became necessary to consider the question of anti-vibration camera fittings and to avoid the use of hand-held cameras.

The necessity for some form of automatic camera caused continual attention to

be paid to this subject by the Photographic Section of the Royal Flying Corps. To be effective a camera of this type should

(*a*) function with the minimum of attention,

(*b*) carry a good number of plates, or possess readily changeable magazines of unexposed surfaces,

(*c*) be free from a tendency to "jamb,"

(*d*) be compact in bulk and light in weight.

Taking these features *seriatim*: (*a*) is of primary importance. It should always be remembered that the mental condition of an observer in a machine flying above the enemies' lines, when in addition to the ordinary flying risks there is the ordeal of anti-aircraft battery and attack from enemy scouts, is not the same as it would be on the ground or even in a ship. The observer must always keep a sharp look out for at any moment he may have to stand to his own gun. Consequently, he is in a state of acute strain and cannot be expected to give that nice attention which a complicated apparatus requires. Therefore, few movements, extreme simplicity, parts to be handled to be relatively large, and strength are required.

As regards (*b*) the calls were sometimes very considerable and so a good number of plates were wanted. Inasmuch as most automatic cameras work by means of magazines of plates, and above a certain number of plates the magazines *tend* to function irregularly, such magazines must be readily detachable in the air. It was found in practice that the magazine for supplying plates was not reliable when an attempt was made to utilise it for more than 18 plates at one charge.

In (*c*) there is stated the necessity for freedom from the greatest element of weakness in all automatic cameras—"sticks" or "jambs," which means that the plate, in its passage through the changing mechanism, sticks in a particular position and refuses to move, with the result that the whole mechanism may be thrown out of gear at what is photographically an important stage in the reconnaissance—may indeed hold up the whole survey and render a return to the ground necessary, if further photographs be required. "Jambs" when they do occur are usually due to the plates themselves, although the fault may arise from a defective working, *ab initio*, of the changing mechanism itself if not properly adjusted before starting. The plates are always held in sheaths of steel, which were moulded by stamping and were made by the hundred thousand. Even with the most perfect system of inspection it will readily be understood that a few defective ones escaped rejection. The metal is also liable to bend and with constant handling an edge may turn up and escape notice and, being included in a bundle in a magazine, may cause trouble. A plate may be slightly too thick and instead of rejecting this, the inattentive photographer may force it into the sheath with the result that there is an increase of thickness of the sheath at the edge and it also becomes wedge-shaped. Here again is a possible cause of a jamb. Sometimes a plate may not be pushed home sufficiently and may project beyond the sheath resulting in a condition tending to a jamb. Another and a large cause of jambs lies in the position of the machine. A plate may be in the position of being changed—the machine turns and must

"bank" steeply to do so. The result is that the plate is not fully carried over and on the return the mechanism may be held and a "jamb" occur. The tendency for this defect to occur was obviated in the later models.

The value of attention to (*d*) is obvious, although not always sufficiently heeded by camera designers, or may have been considered by the designer and neglected by the evolutionists through whose hands the apparatus passes before it reaches the squadrons in the field. There was unfortunately a continual tendency to complication and to increase in weight and bulk. This is almost inevitable. As the standard of excellence rises with increase of experience, there comes the desire to go one better and this frequently means impaired construction and the birth of the idea that additional "gadgets" are necessary. We may add to this also the fact that designers of apparatus do not always fly, and with the best intentions in the world, fail to appreciate all that complication, bulk and weight really mean to the fighting observer.

Automatic Cameras.

The first automatic, or rather plate-changing camera, because it was only partially automatic, was the "C" type and was developed from the "A" camera. Consider an "A" camera placed vertically on a table with the lens end downwards. The *M/W* holder has been removed and in its place has been permanently fitted a frame which is in length about equal to three times the width of the shutter framework which terminates the body. Essentially this framework is merely a repeating back with two openings, through one of which the exposure is made and through the other the exposed plate eventually drops into the final receptacle. Centrally in the frame and extending about one-third of the length is a slot, up and down which a handle works. In the thickness of the frame, working in grooves and connected with this handle is the changing device, a sheet of brass which serves the function of pushing the exposed plate out of position after exposure into the place above the receptacle at the under side of the right hand of the framework, into which it falls by gravity. When this has been done, two strips of rack, fitted to either side of the sheet of brass, engage with a pinion across the framework, and on pushing the handle home towards the right hand, the shutter is wound up ready for the next exposure. Whilst this is being done, the brass sheet covers up the camera opening so that the next plate in the magazine which falls down by gravity into the focal plane is not exposed. On withdrawing the handle back to the left the plate is ready for exposure. The exposure was made by pulling a cord attached to a peg situated close to the finder, which released the shutter. This was a later development—in the earlier types the ordinary release of the "A" camera was employed. It must be remembered that the shutter in the "C" type camera was the original "A" camera shutter unchanged and alteration of slit width was made as in that camera. The plates in their sheaths were held in wooden magazines. A magazine full of plates was placed in position and a second magazine—empty—was fixed on the under side of the frame to receive the plates after exposure. The operation of using this camera was simple. The handle was on the left hand of the frame at the commencement of the cycle. This was pushed over to the right, care being taken to give a sharp forward move-

ment when nearing the end of the run—this was necessary in order that the blind should catch. The handle was now brought back to the left hand. The lid of the receptacle for exposed plates was opened, folded back and caught, the lid or shutter of the magazine was similarly treated. The plate was now ready for exposure. The cord was pulled at the proper moment and the cycle of operations repeated for the next exposure. The magazine, when empty, could be replaced by a fresh one quite easily. The magazines for unexposed plates and for receiving exposed plates were of the same type and interchangeable, but if need be—and the plan was often followed in practice—the receiving magazine could be larger than the supply so as to obviate the necessity for so many changes, which the use of a smaller magazine would entail. On the top of the frame at the right-hand end was a recording device to show the number of exposures which had been made. Experience showed that the "C" type of camera was a step in the right direction. Mounted in a rigid fitting,

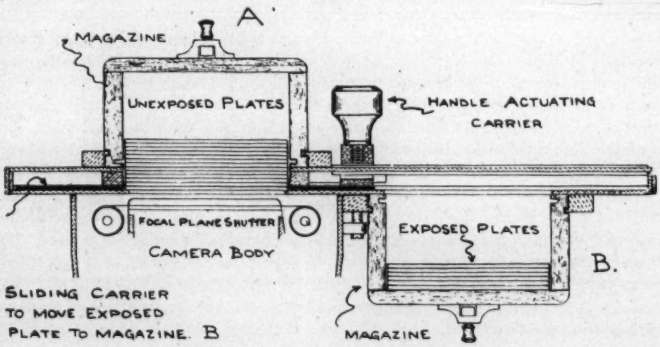


Fig. 9. Diagram showing the principle of the "C" type changer as employed on the first changer camera used by the R.F.C.

it overcame the principal difficulties met with when the hand-held "A" camera was used and it enabled a series of pictures to be made with relative rapidity. It was, however, only a partial solution of the problem which pressed with increasing force on the Section. Given that an automatic camera was desirable, it was obviously necessary that attempts should be made to approach as nearly as possible to an apparatus which would fulfil that condition (Fig. 9).

The next item in the chain of evolution was the "L" type, which was known as a semi-automatic plate changer. In this apparatus there is a distinct departure. In the first instance the camera was made wholly of metal, wood being utilised only for the magazines. The "L" camera consists of a cast metal chamber which contains the shutter and the actuating mechanism, a metal framework, similar to that used in the "C" type, which carried the safety shutter, the plate magazines and the recording device and a cone tube fitted to the camera chamber which held the lens. The

general appearance is indicated in Fig. 10. It should be noted that the length of the lens tube permits of lenses, whose principal focal distance varies between 8¼" and 10¼", being used (Figs. 11—15).

In this apparatus, changing the plate and setting the shutter is performed in one operation as in the "C" type, but there is this important difference—that this function can be performed by means of a system of mechanism operated by hand, or by means of motive power derived from a small independent propeller, fixed on the exterior of the machine, which is driven by the air current met as the aeroplane travels through space. Furthermore, the camera can be used intermittently for single photographs, or continuously for a series determinable at will so long as there remain plates in the magazine to be exposed. This, it will be seen, constituted a very considerable advance in aerial photography. In the figure the boxes are observed in position. On the right-hand side of the figure is the setting lever 1013. This operates the plate changer and sets the focal plane shutter. Consider the lids of the plate boxes closed. Moving the lever back to the end of its stroke and forward to the same extent sets the shutter. The lids of the plate boxes are now opened. The plates in the box fall down into position by gravity, one above the other as in the box, the first one in the focal plane. If now, the plunger 1040 be depressed sharply, the shutter is released. The plate is changed and the shutter reset by bringing back the lever and pressing it forward again when the apparatus is ready for the next exposure. So far the apparatus has been hand worked; when operated by means of the propeller a series of pictures may be made by the operation of a lever and the camera may be put into action when at a distance from the observer by means of a Bowden wire. In this way the observer is freed from the necessity of continued attention during the production of a series of pictures. To transfer the apparatus from hand release to lever release, the end of the Bowden wire—which terminates in a loop—is inserted in the opening at the end of the tube containing the shutter release plunger, and the loop is put over a screw at the end of the plunger and secured. On pulling the automatic lever, the plunger is pulled down and the shutter, if wound up, is released. The changing lever is pulled over by hand and allowed to return. This brings the sliding changer into the back position. The end of the flexible shaft is now inserted in the opening provided and made secure. The magazine full of plates is now placed in position and the receiving magazine made secure, both shutters are withdrawn, bent back and secured. The thumb coupling screw is then withdrawn and inserted in the hole provided in the hand changing lever and made firm. A plate has now fallen into the focal plane and is ready for exposure. On pulling the automatic lever, exposure is made. If now the propeller blades be rotated, changing of the plate commences and the shutter is set. When the plate is changed, the propeller runs free until the exposure is made, when the cycle again commences. The time taken to change the plate in an air velocity of 50 m.p.h. is about 10 seconds, so that allowing for lags and losses about 5 plates per minute can be exposed in the camera under this condition. The Bowden wire release is generally fitted to a vertical strut on the left-hand side of the observer when seated in the cockpit of the machine. At the same time it is observed that a cord may be fitted to the hand lever and may then be guided to

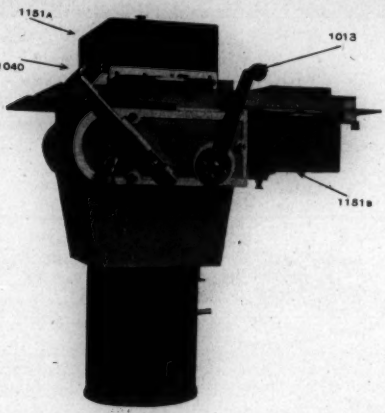
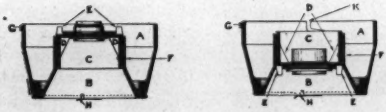
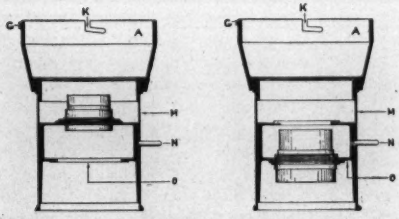


Fig. 10. The "L" type camera of the R.F.C. which was the second of the changer types used



Figs. 11 and 12. Cones of the "L" camera for lenses of short focal distance.



Figs. 13 and 14. Cones of the "L" camera for lenses of medium focal distance.

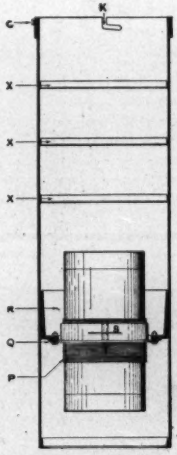


Fig. 15. Cone of the "L" type camera for a lens of 20 in. focal distance.

a convenient position for the observer so that if desired the operation of changing

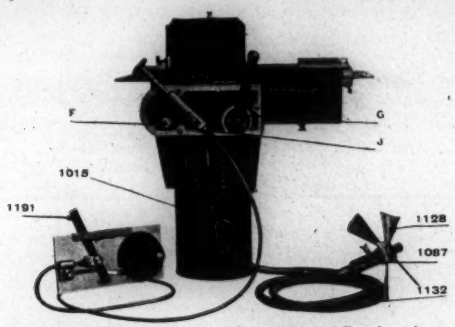


Fig. 16. An "L" type camera with propeller and Bowden release.

may be performed by hand without the necessity of employing the propeller. The Bowden wire method of release and the hand lever worked by cord give the opportunity for placing the camera in a position away from the observer if such arrangement be necessary. The position of the propeller must be such that it receives a continuous current of air. It must be rigidly fixed. Two propellers are provided, one for "forward" and the other for "trailing" drive. The correct position is such that looking at the propeller end of the shaft it must revolve in a clockwise direction so that the correct movement may be given to the mechanism of the camera (Figs. 16, 17).

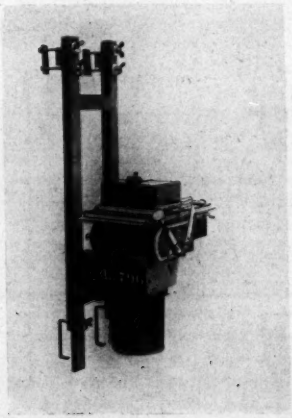


Fig. 17. An "L" type camera fitting employed when the apparatus was fitted to the exterior of the aeroplane.

The lens is mounted in a circular tube which is attached to the aluminium camera body and is constructed of such a diameter that it will take the largest lens required. By an ingenious arrangement, the lenses of foci between 8 and 10½ inches can be adjusted, and when the correct position is found, can be permanently fixed. Above the rear of the lens and inside the camera box is fitted the safety shutter which covers the lens and prevents exposure of the plate whilst the shutter is being changed. The arrangement for lifting this safety flap at the proper moment before the actual exposure provides for the correct adjustment in this respect.

It remains to be stated that there is provision made by means of an external adjustment for altering the spring tension which controls the period taken up by the travel of the blind, and this together with the variation of slit width enables ample variation to be made. Taking an average of a series of tests the exposures may be readily varied between 1/75th and 1/300th of a second.

The next semi-automatic type introduced was a modification of the "L" camera and was known as the "LB." The mechanism in the improved form was much

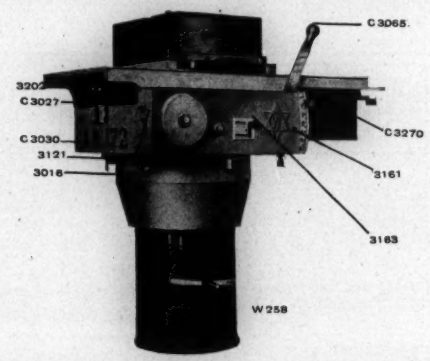


Fig. 18. The "LB" camera, the third changer camera of the R.F.C. This camera is similar to the "L" camera in appearance but is a great improvement on that apparatus. It is fitted with a self-capping detachable shutter and the apparatus in the illustration has the cone for an 8·25 or a 10 inch lens.

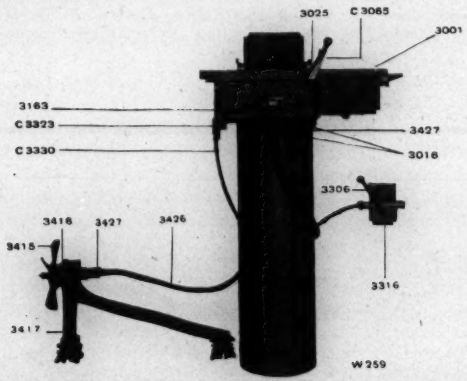


Fig. 19. The "LB" camera fitted with a cone for a 20 inch lens.

simplified—there was a smaller sized camera body and a reduced weight. The most interesting modification was the introduction of an easily detached self-capping focal plane shutter which could be removed without affecting the other portion of the mechanism. When the camera was set for automatic operation, pressure on a trigger form of release makes the exposure and sets going the means whereby the plate is changed and the shutter reset. There was as well as this improvement a means whereby the camera could be quickly changed from hand to power, a ratchet form of plate changer, and an exterior mechanism for altering the width of slit in the shutter. The camera could be readily adapted for lenses of any focal distance from 4″ to 20″. The camera is actuated by air propeller when power driven. In external appearance the camera is very similar to the "L" save and except that the plunger release is absent. The standard "L" type lens cone is employed for lenses of 8″ to 10½″ focal distance and a similar tube for lenses of greater focal length. The same plate magazine is used (Figs. 18—22).

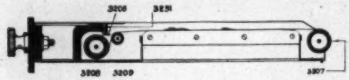


Fig. 20. Sectional view of self-capping shutter of "LB" camera.

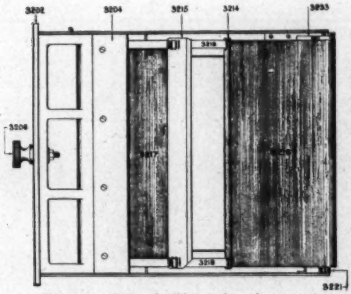


Fig. 21. Plan of self-capping shutter of "LB" camera.

To operate the camera by hand the knob on the side indicator is set to "Hand" and the shutter is then set by drawing the lever (as in the "L") on the right hand backwards and forwards to the limits. The supply and the empty magazines are then

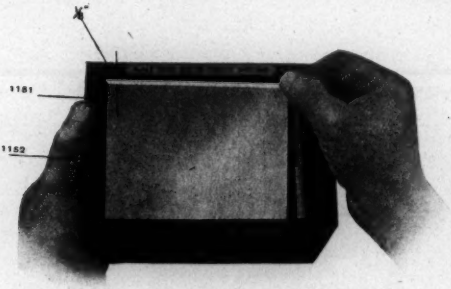


Fig. 22. The plate-holding box, or magazine, of the "L" and "LB" cameras, showing the mode of insertion of the plates in their sheaths in the box.

placed in position and their shutters withdrawn and locked back. When the shutter of the supply box is withdrawn, the plates fall by gravity, the first one into the focal plane. Exposure may now be made by pressing the trigger release at the end. When the plate is exposed, one complete cycle of the movement of the hand-setting lever changes the plate, allows another to drop into the focal plane and resets the shutter for the next exposure. Exposure may also be made by means of a Bowden wire operated from a distance in the manner adopted with the "L" camera (Fig. 23).

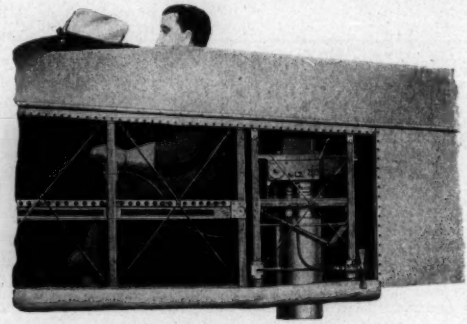


Fig. 23. The "LB" camera with tube for lens of 20 inch focal distance fitted in machine behind the observer, with propeller for driving and Bowden release shown.

To change over to power the movements are simple. The magazine lids are closed and the shutter is then set and the Bowden release wire attached. The indicator is then set to "Power" and this puts the hand-changing system out of action. The flexible driving shaft is then coupled up as in the "L" and the magazine lids are withdrawn. Under normal conditions the change takes place in about 10 seconds and the propeller runs free when the work has been done and no exposure is made. If it be desired to convert back to hand, the flexible shaft must be removed and the indicator set to "Hand."

Owing to the large variation in the focal distance of lenses used, differences are shown in the lens tubes. For the 4" lens the mount is one inverted cone within another with a tube which can be used both ways so as to vary distance, there is the ordinary tube as used with the "L" and the long sleeve used for 20" lenses. These variations are shown in Figs. 11–15.

The removable shutter shown is held in an aluminium frame which slides into the camera body and is withdrawn by the knob marked 3202 in Fig. 21.

The demand for large sized pictures, as well as a camera which could be automatically worked, led to further constructions which materialised in what is known in the Service as the "BM" type semi-automatic camera. This was just coming into use at the time of the Armistice. It had been settled by International Photographic Conference that the large plate should be 18 × 24 cms., and the "BM"

camera was made to take this size. The camera is semi-automatic in its action, i.e. the function of changing the exposed plate and resetting shutter are made in one cycle, when the exposure is then made and the operation afterwards repeated. The shutter is self-capping and is carried in a cast aluminium box which is detachable from the camera. A fixed tension is used, the width of the slit being adjustable from $\frac{1}{2}$" to $1\frac{1}{2}$" by means of an exterior knob provided with a pointer working over a dial. The plates are held in sheaths in detachable magazines holding 12 plates. Power for driving the mechanism is derived from an air-driven propeller attached to the machine and connected to the camera by means of flexible shafting. The exposure shutter is released by means of a lever connected with the camera, actuated by a Bowden wire. The standard lens tube or cone is employed; this is detachable from the body which contains the mechanism and plate-containing units, and the cones are interchangeable between different bodies. Lenses of different focal distance can be used but the usual lens employed is one of 20" focal distance. The complete automatic mechanism is mounted in a cast aluminium gear box which is secured to the side of the camera and is removable. An indicator shows the number of exposures made, and another indicator suitably placed at the end of the box, so that it can be easily seen by the operator when the camera is in the machine, shows when the change of exposure has been effected and that another plate is ready to be exposed. The apparatus complete is shown on the table (Fig. 24).

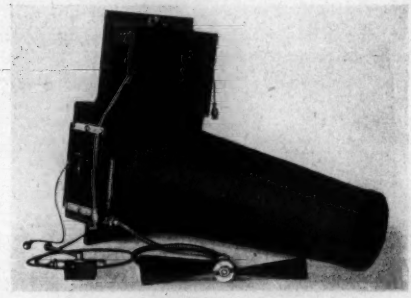


Fig. 24. The "BM" magazine camera for plates 24 × 18 cm., showing the magazines attached, with the propeller and the release. This camera is fitted with the full sized standard cone to which reference has been made in the paper.

By means of this camera admirable work has been done, but its weight (over 80 lb.) is a serious objection.

During the last six months very serious attention has been given on the part of the Photographic Section of the R.A.F. to the production of a truly automatic camera suitable for use with films and an apparatus in experimental form which is now ready for trials has been designed and constructed in the Experimental Section. This camera will be truly automatic and self-contained, the mechanism being clockwork. The standard cone will be employed. It will fulfil the very desirable condition of being able to make a large number of exposures 24 × 18 cm., purely by pressing a button so that it may be used either in a two-seater machine with an observer, or what is very advantageous, in a single seater, as it will demand little or no time and attention from the pilot.

It may be stated that the use of a continuous film camera for aerial purposes is not new. Actually a camera known as the "Aerocam" designed and built by Messrs Williamson was first employed by the Photographic Section of the R.F.C. as early as October 1915 and was subsequently used in France and Egypt and, by the courtesy of the Corps, by the R.N.A.S. in the Mediterranean. This camera—an illustration of which is shown—is a wind driven instrument and made a continuous series of pictures 5 × 4 in size, perforating its own film and registering the altitude and bearings on each picture automatically. A camera for similar purposes was also excellently designed and made by Mr E. F. Moy for the R.N.A.S. and used on one of our Experimental Stations. A continuous film camera for small films, but not according to our ideas, was designed and made and offered to the Allies by an Italian firm early in the war. Later in 1917—18 an admirable automatic camera was designed by Col. Douhet of the Italian Army for 13 × 18 cm. films, wind driven; this was coming into active use when hostilities ceased. Of a more ambitious type was a camera entirely automatic, for films whole plate in size, designed by Mr Workman of the Cinechrome Company which was known as the "Craftsman." This camera, which was admirably made, was undergoing trials at the cessation of hostilities. Excellent designs according to different systems have been carried out in France and the apparatus has functioned well in the air. An American film camera for 5 × 4 films, automatic in type, known as the Brock camera, was offered to the Allies early in the war. This was before the entry of the U.S.A., but since that event the Photographic Section of the U.S.A. Air Force has given much attention to the subject and has produced an automatic film camera. This brief résumé will give you sufficient information to show that the Services of the Allies have devoted much attention to this problem.

There are two difficulties with films, one mechanical and the other photographic. The mechanical difficulty is the want of flatness of the film, and the devices to secure flatness are all more or less complicated. Upon the table there is placed a film camera captured from the Germans, in which the film is kept flat in the focal plane by pressing it against a glass plate. On the other hand the French and Americans have employed suction devices. The second difficulty is perfectly well known to users of plates and papers, so that it is not necessary to make any comparison in this paper as to the ultimate results from the two materials. It is not, however, entirely an essential difficulty and will no doubt be overcome. Remarkably fine results have been produced with large sized films; indeed, where the conditions are suitable it would not be perhaps accurate to say that a plate would have produced any better pictures. Even though in general the photographic results may not be quite so good as with plates, there are great and manifest advantages in the use of films. There is no doubt that there is a great peace time future for aerial photography for survey purposes, and the advantages of being able to make a rapid preliminary survey of a tract of country need not be laboured.

Similarly there has been designed and made a 5 × 4 camera for films for Naval purposes, in which a simple movement of a lever changes the film and sets the shutter. An example of this camera is on the table.

Kite Cameras.

Interesting attempts have been made from time to time to obtain photographs by means of a camera suspended from a kite. One of the most promising of these attempts was made by Mr G. A. Barrett. We had an opportunity of trying his apparatus in the early days of the War, when some interesting negatives were made, some examples of which I will show you. The apparatus was used with some success in exploration in Egypt before the War, but for reasons which will be understood, its usefulness in military operations was very small—for the simple reason that the ground party working the kite would very soon receive the unpleasant attentions of the enemy and be compelled to cease their operations.

Camera Fittings.

A reference has been made previously to the general question of fittings and their extreme importance. In the first instance the assumption was made that by rigidly fixing the camera to the machine, improvement with respect to freedom from distortion and the effects of vibration would be made, and from this view arose the first fitting which was a simple frame attached by bolts and wing nuts to two vertical members in the framing of the machine. To this frame the "A" camera was attached by leather straps. The same form of fitting was adopted for the "C" camera and practically the same for the "L" camera when an exterior fitting was used. Examination of the "L" camera will reveal two holes, one on each side of the camera body, and through these holes were passed stiff tubes or rods which were secured to the fitting.

There is, and always has been, an objection on the part of pilots to exterior fittings or protuberance of any form, simply because they always reduce flying speed, and moreover, in causing unequal resistance, they increase the pilot's difficulties. From the photographic observer's standpoint they make the work of manipulation more difficult than would be the case were the apparatus inside, because all the operations have to be performed against considerable wind pressure. The fixing of the camera in the machine therefore meets with the approval of all. When we come to the matter of camera fittings for the interior of the machine —the camera is usually placed in the observer's cockpit—it is essential as a first action so to design the fitting that it does not in any way interfere with the observer's freedom of movement. The number of fittings made in this respect has been considerable. The French Service has been particularly active with interior fittings. There came also, as a result of experience, the desire to guard against the effect of movement—sudden turns and twists of the machine—and vibration, and we have as a result some form of cushioning. Cushioning of cameras in machines was effected by suspension systems of springs or rubber, in which the medium was in tension or compression, or by framing resting on rubber sponge, which proved most effective in use. In addition, felt, compressed fibre, tennis balls, and hair have been employed.

I exhibit here several typical devices—the fittings themselves and illustrations showing their use in machines. It is not possible to say that such and such a fitting shall be placed in every machine, for the matter has to be considered in every

instance. It may be stated that no machine has ever been built specially for photography although it was known beforehand that the machine would be used for photographic purposes. I do not think that in any case the requirements of photography were allowed to influence design, although signs were not wanting that as a result of continual representations from those who were interested that something might eventually be done in that respect.

The object of a "fitting" is to be a support for the camera in the machine and to fill this function in such a manner that it either avoids vibration—which is practically impossible—or to reduce it to such an extent that the harmful effect is practically negligible. So far as regards freedom from vibration the difference between a camera which is rigidly fixed to the machine and a camera supported in an arrangement held in the machine but designed to reduce vibration is demonstrated in the test photographs which I now show on the screen (Fig. 25).

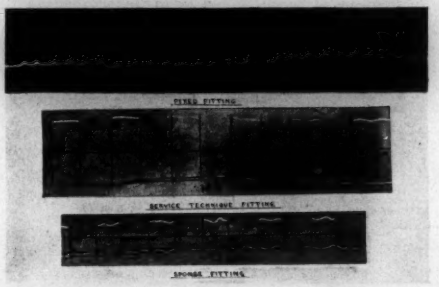


Fig. 25. Diagrams showing the results of some camera fitting tests.

The test is carried out in a very simple manner. A light or two lights are fixed upon the ground and in addition a third light which can be regularly eclipsed at certain intervals. The machine with the camera fitted flies over this arrangement at night time with the camera shutter fully open. Two traces are produced, one of these being continuous and the other discontinuous because the source has been eclipsed at certain intervals. This enables the time value of any length of the trace to be determined. In the example now shown one of the traces shows the effect with the camera rigidly fixed, the second the special fitting designed in France and known as the "Service Technique" type, and the third the camera cushioned with rubber sponge. The marked influence of the properly designed fitting in the reduction of the effects of vibration is here clearly shown. The simplest fitting employed was the first one adopted. This was the entirely rigid type employed to hold the "A" camera to the exterior of the machine and it was also adapted eventually to take the "C" changer already described. As will be observed from the example, this has a simple wooden frame made to take the camera, which was fixed firmly to two of the vertical members between the longitudinal members of the framework

of the machine. This was afterwards replaced by the cushioned fitting now shown which was placed inside the framework of the machine which took the "C" and "L" and eventually the "LB" as well as the wireless apparatus. Cushioned fittings of the form shown were employed for the wide angle and the "P" type cameras either singly or in pairs for stereoscopic work. The "Service Technique" fitting, which has been considerably modified by the R.A.F., is shown on the table (Fig. 26). So far this form has been the most successful (see Appendix 2). In a series of tests made with the different forms of support it was found that the ratio amplitude of transmitted vibration to the camera, taking the fittings in the order, "Service Technique"—"Service Technique" supported on sponge rubber—sponge rubber supported fitting alone, are as 2:3:4, that is to say that the "Service Technique" fitting alone gave the minimum amount of vibration and that the mere fact of supporting this fitting on rubber not only did not reduce this vibration standard but increased it. This curious fact is probably due to the fact that the particular rubber

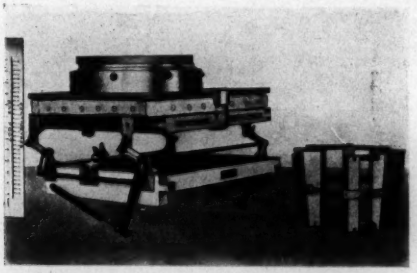


Fig. 26. The French "Service Technique" fitting, as adapted to the use of the Royal Air Force.

has a vibration period of its own and that slight vibrations set up were amplified. I mention this as an instance of the result of slight modifications even when made on apparently correct lines, and how in every case a particular arrangement has to be carefully tested before it can be said that it will be effective.

For naval work from seaplanes and flying boats the conditions of photography are different in many respects from those which obtain when operating over the land, more especially when working within the zone of active operations on the land. As stated previously, save and except for photography of the coast line, automatic cameras are not used, and for the vast majority the simple hand-held apparatus suffices. Much of the work is of particular objects which occupy a relatively small area of the plate, such as a submarine, which may appear at any moment on any quarter of the machine which is flying, and necessitate rapid action on the part of the observer if a record is to be secured. A large proportion of the work is oblique, as in the regularly made registers of convoy formations which have been found to be so valuable. To meet the particular necessities and to secure the

advantages in so far as may be practicable of a fitted camera, special devices have been evolved which can be employed to hold the camera, giving extreme freedom of movement and at the same time a large security from the effects of vibration and distortion. I show illustrations of those used on seaplanes, flying boats and on airships (Figs. 27, 28).

The favourite form of camera for naval work was a light apparatus, which could be held in the hand, fitted with a lens of from 6″ to 8″ principal focal distance. It may be stated that the flying height for aircraft over the sea for patrol work alone was generally very low as compared with that of land machines. There is however a great advantage with a fitted camera, which is, that it is always in its place, and is

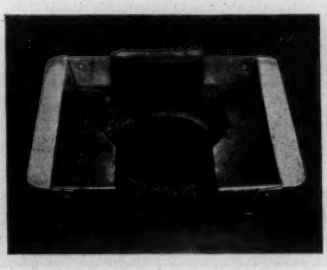


Fig. 27. A fitting used in seaplanes for the Type 18 camera; aluminium with sponge rubber cushioning.

Fig. 28. A fitting used on seaplanes and airships to take cameras used on Naval patrols. Here the camera was held in a band fitting round the body and the whole could be quickly lifted out of the fitting if the camera was wanted free.

protected by reason of its position, for the aviator observer is none too tender in his treatment of photographic apparatus. With the fittings employed the camera is readily and quickly detachable when required, so that if the desired negative could not be secured when the camera was held in the fitting it could be readily removed and used as a hand-held instrument.

From the point of view of value as a help, the use of photography as an aid in training for war-like purposes may receive brief reference. No effort has been of greater value than that devoted to instruction and training in practical gunnery. All those who pass through a training in this subject—which means, of course, all pilots and observers—must use the Hythe Gun Camera. The latest type of this apparatus is shown on the table. To all intents and purposes, as far as regards appearance, it is a Lewis Gun, its weight and balance are the same, it is used in the same way, only instead of firing bullets it takes photographs and the photographs

furnish a record of the accuracy of the aim. The instructor can send two pupils up into the air for a combat and can afterwards say, by examining the photographs, whether or not either man's bullet, had a real gun been used, would have accomplished the desired purpose, and if not the extent of the error and what alterations would have been necessary. Hundreds of thousands of photographs have been made for this purpose alone and the camera guns designed by this Service have been employed by the whole of the Allied fighting forces (Fig. 29).

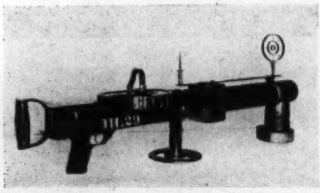


Fig. 29. The Mark III Hythe Gun camera for use in training in aerial gunnery.

NOTE. The author is indebted to Mr Colin M. Williamson, of the Williamson Kinematograph Co., London—who was intimately connected with the development of the "L" and "LB" cameras—for the loan of the blocks for Figures 10–16 and 18–23. Detailed descriptions are given in the pamphlets on these cameras which are issued by the Company, to which those who desire further information are referred. To facilitate reference in this text to the illustrations employed, recourse has been made to certain descriptions used in the pamphlets, for which acknowledgment is made.

APPENDIX

1. This has been done since the reading of this paper. For an admirable account of what has been accomplished by British lens makers in providing new lenses see the Transactions of the Royal Photographic Society (*The Photographic Journal*, Vol. LIX. No. 4, April 1919).

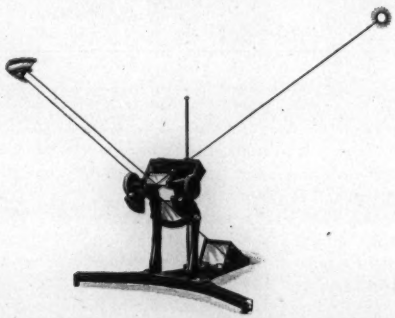
2. The Photographic Section of the French Aerial Service introduced the fitting known as the "Service Technique," which does not however appear to have been used to any extent. From this original the Photographic Section of the R.A.F. with the E.F. developed the spring mounting shown in Fig. 26, which is quite different from the original French type, only the essential details—the spring and the bell crank—remaining. Since the reading of this paper another fitting or "mounting" has been designed by the R.A.F. which, whilst on the same lines and equally efficient, if not more so, is about one half the weight of its predecessor. This fitting has no rubber sponge, but relies for shock absorption and elimination of vibration on two springs. This is known as "Camera Spring Mounting No. 21."

EXHIBIT OF THE HUSUN AZIMUTH SIGHT

By H. HUGHES & SON, Ltd.

Exhibited, 13th March, 1919

The Husun Azimuth Sight is placed on the compass bowl for taking bearings. The instrument consists of a stand on which is mounted a pedestal, which carries what is referred to as the upper prism, a magnifying lens and two shades. The setting of the upper prism is indicated by an arrow on the face of the milled head adjusting screw. A large prism is mounted on the fore arm of the stand by means



of which an image of the compass card is projected to the observer's eye. A lubber line is marked on the base of this prism. A shadow pin is mounted on the stand in line with the lubber line and in a plane vertical to the upper prism.

How to take Bearings

To take the bearing of an object the sight is rotated on the compass card to the approximate bearing, and the upper prism arrow upwards, revolved on its axis till the object appears on the lower edge of the prism and overlaps the image on the card seen through the lens.

The observer looking through the lens can now see two lines in the large prism, which by moving the head sideways can be made to coincide; maintaining this coincidence adjust the whole sight by rotating it till the object, seen through the upper prism, coincides with the line in the large prism.

The bearing of the object may now be read on the compass card from the object itself without regard to the line in the large prism which is only required for setting and not reading the sight, and it will be found that the object and compass card maintain their positions whether the head is moved to one side or not.

REPLY BY I. MAUD MATHEWS TO E. M. NELSON'S NOTE ON DISPERSION FORMULAE

In *Trans. Opt. Soc.* 19 (1918), 186 there was published a note by Mr E. M. Nelson applying some unquoted formula in a previous number* to Dr Hopkinson's indices†. As the writer was not aware of the existence of Mr Nelson's note until it was in circulation, this is the first opportunity of commenting on it. It therefore seems desirable to apply the formulae

$$n = H\lambda^2 + A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} \qquad \ldots.(1),$$

or

$$n = L + \frac{P}{\lambda^2} + \frac{Q}{\lambda^4} + \frac{R}{\lambda^6} \qquad \ldots.(2)$$

to Dr Hopkinson's indices. As pointed out in the previous article* the formula (1) takes account of one term due to the red absorption band and two terms due to the violet band, and is not suitable for dense flints, in which the violet band is nearer the visible region than in the crowns.

To determine H, A, B, C the formula (1) requires four data, not two—as Mr Nelson's "Data: Lines C and F" seems to imply. Mr Nelson has not supplied the writer with the formula used—but the wave-lengths he used were Rowland's to 7 or 6 significant figures.

As remarked before,* the best method of applying the formula (1) to any number of glasses is to calculate the constants H, A, B, C as linear functions of the four given indices, the coefficients being functions of the corresponding four wave-lengths. These coefficients are admirably adapted to logarithmic calculations; as they involve the six pairs of difference of the four wave-lengths, the latter should be approximately equidistant. It is only a few minutes' work to obtain L, P, Q, R for (2) once the linear functions for H, A, B, C are known. Subsequently a few lines of work will test any given glass.

For one glass the wave-lengths supplied by Mr Nelson were also used—for the rest of the calculations they were taken from Kaye and Laby, *Physical and Chemical Constants*, p. 75, and are Rowland's wave-lengths corrected by Fabry and Perot's standards, given to 6 or 5 significant figures. In the working B, D_2, F, H_1 were the reference lines and 7 figures were retained, thus giving the last digit quoted in the numerical constants. This digit had sometimes to be altered by 1 or 2 units, but only in the case of Mr Nelson's wave-lengths was it 3·3 units. Thus wave-lengths to 5 and 6 significant figures will not determine indices to the fifth decimal place with certainty.

* *Trans. Opt. Soc.* 19 (1918), 94.
† *Proc. Roy. Soc.* No. 182 (1877).

λ in cms.

$$n = -h\,10^{5}\lambda^{2} + a + b\,10^{-11}/\lambda^{2} + c\,.\,10^{-21}/\lambda^{4}.$$

Glass	Angle measured					(*n* calculated − *n* observed) . 10^5									
		h	*a*	*b*	*c*	*B*	*C*	D_2	*E*	*F*	*G'*	*G*	*h*	H_1	
Hard Crown α ...	3	3·03	1·50679	3·777	6·28	2·8	2·1	3·2	4·0	3·4	3·8	—	—	3·7	Mr Nelson's wave-lengths
" ...	3	3·03	1·506757	3·777	6·28	−0·5	−1·2	−0·1	+0·7	+0·1	+0·5	—	—	+0·4	
" ...	3	3·00	1·50675	3·78	6·2	+1	0	0	+2	0	0	+1	+1	−1	Kaye and Laby's wave-lengths
Hard Crown β ...	2	2·37	1·50682	3·87	5·7	0	0	+1	−2	0	−1	+3	−1	0	
Soft Crown ...	3	2·76	1·50351	3·93	8·4	0	−2	0	−4	0	+1	+3	+2	+1	
Titano-silicic Crown	2	3·30	1·53122	4·22	12·1	−1	0	0	−2	0	+2	+3	+1	−1	
Extra Light Flint...	3	4·66	1·52869	4·31	18·4	+1	0	0	+1	0	0	+1	+4	−1	
Light Flint ...	3	4·17	1·55825	5·29	23·6	0	−1	0	−3	−1	+1	+1	0	−2	
Dense Flint ...	3	4·78	1·60308	6·28	34·8	0	0	0	0	0	+5	+6	+7	+1	

$$n = l + p\,.\,10^{-11}/\lambda^{2} - q\,10^{-20}/\lambda^{4} + r\,10^{-29}/\lambda^{6}.$$

		l	*p*	*q*	*r*										
Extra Light Flint...	3	1·52299	6·77	2·61	2·85	0	−2	+1	+2	0	−3	−2	0	0	Same glasses as above
Dense Flint ...	3	1·59728	8·79	1·09	2·94	+1	−1	0	+1	0	0	+1	+1	0	
Extra Dense Flint	1	1·62265	9·53	0·56	2·99	+1	−2	0	+1	0	+4	+3	+1	−3	

On Dr Hopkinson's spectrometer the angle was read off from two verniers reading to 10″; he usually made determinations at more than one angle of the prism and took the mean. The mean of the observed values is used in these calculations. For the Hard Crown prism α, angle 60°

an error of 10″ in deviation gives error $3{\cdot}15 \times 10^{-5}$ in index,
„ 10″ „ angle „ $3{\cdot}23 \times 10^{-5}$ „

prism β, angle 45°

an error of 10″ in deviation gives error $5{\cdot}15 \times 10^{-5}$ in index,
„ 10″ „ angle „ $3{\cdot}74 \times 10^{-5}$ „

Contrary to Mr Nelson's conclusion a perusal of the accompanying table rather tends to support the formula (1) for crowns and (2) for flints.

NOTE ON THE PAPER "SOME GENERALISED FORMS OF AN OPTICAL EQUATION"

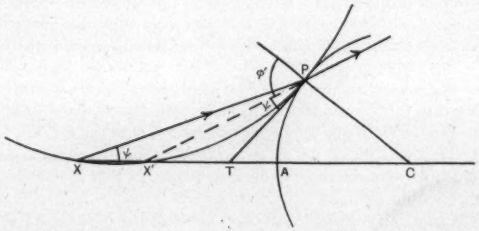
By ALICE EVERETT, M.A.

In the paper referred to [*Trans. Opt. Soc.* 20 (Nov. 1918), 23] ϕ, ϕ' are the angles of incidence and refraction, ψ, ψ' the inclinations to the axis of the incident and refracted rays. P is a point on the refracting surface, and X, X' are the points where the incident and refracted rays XP, $X'P$ cut the axis.

In his generalised equations Mr T. Smith introduces a new angle

$$\gamma = \phi + \psi' = \phi' + \psi,$$

which he remarks, on p. 25, is not readily visualised. The following rather curious little property of the angle γ may perhaps be worth mentioning as possibly helping to visualise it. In the figure on p. 24, let a tangent be drawn at P to the circle circumscribing the triangle PXX' (see accompanying diagram). Then γ is the



angle between this tangent and the normal at P (CP produced) to the refracting surface. For the angle between the tangent at P and the chord PX' is equal to the angle PXX' or ψ, which the chord subtends in the opposite segment of the circle; while ϕ' is the angle between the chord PX' and the produced normal.

The angle γ is also twice the angle between the bisectors of (1) the angle between the incident and refracted rays, and (2) the angle between the normal and the axis.

REVIEW

"The Theory of Modern Optical Instruments." By Dr ALEXANDER GLEICHEN. Translated from the German by H. H. EMSLEY, B.Sc., and W. SWAINE, B.Sc., with an Appendix by the Translators on Range-finders. [London: Published for the Department of Scientific and Industrial Research by His Majesty's Stationery Office, 1918; pp. xii + 376, diagrams 241 + (Appendix) 29. Price 12*s*. 6*d*. net.]

This book consists of two parts: the first, which only occupies one quarter of the volume, deals with the elementary theory of image formation and the theory of stops; the second is composed mainly of descriptions of optical instruments made by the leading German manufacturers. There can be little doubt that it is the latter feature which has led the Committee of the Privy Council for Scientific and Industrial Research, in the absence of a compilation dealing with the products of British firms, to choose this particular volume from the writings of Dr Gleichen for translation into English and publication during the War.

The mathematical portions of the book are of an extremely elementary character. They are concerned with instruments from the point of view of the user, and do not touch the distinctive problems connected with modern developments in optical instruments. To this extent the title of the book is misleading. The author has attempted to secure uniform treatment of all parts of optical theory by effecting a compromise between rival conventions. The resulting system is in some respects unfortunate, and is not applied quite consistently throughout the book. The measurement of distances in opposite directions in object and image spaces is apt to be confusing, particularly when two systems are combined so that the image for one system is the object for another. The original text contains no explicit statement of the conventions employed, and the appendix dealing with these which the translators have added at the end of Part I could with advantage have been amplified and placed at the beginning of the book.

On the title page this work is described as "a Reference Book for Physicists, Manufacturers of Optical Instruments, and for Officers in the Army and Navy." It is not therefore surprising to find that Military instruments figure largely among the contents. Other instruments are however by no means neglected, and this section has evidently been largely compiled from the catalogues of manufacturers with the intention of advertising their goods. Needless to say only instruments of German manufacture are referred to. Opinions will differ as to the wisdom of extending the advertisement by the issue of an English edition of this book, but there can be no doubt as to the value of a book containing illustrations of the various forms of prismatic telescope which have been evolved in recent years. The chapter on photographic lenses is chiefly a compilation of constructional data of various types of objectives, apparently abstracted from Patent Specifications. The space would be more usefully occupied by an explanation of the principles on which they are constructed.

The translators have produced a clear English text, and have added very materially to the value of the volume by inserting a number of footnotes, appendices, and a bibliography including references to English works.

Particularly noteworthy is the appendix on the Barr and Stroud Rangefinder. It is to be regretted that it has not been found possible to deal as adequately with other British products. As in many other German scientific and semi-scientific books the original text appears to have been decidedly deficient in references to the work of non-German investigators. Only two references to British workers have been noted in the body of the book. This has been to some extent remedied by the translators. Cases are not wanting in which credit is given to German workers for results due to others. For example Young's construction for a ray refracted at a spherical surface is ascribed to Weierstrass. Additional footnotes might have been added in a few cases where the meaning of the text is ambiguous or obscure.

The letterpress is clearly printed and varied type is used with good effect. The book is very fully illustrated and most of the figures leave nothing to be desired. In some cases, however, the lettering of the diagrams is indistinct or erroneous. Some of the figures, such as 34 and 35, may puzzle a student, as they show impossible conditions. Fig. 45 III is not drawn in accordance with the numerical results tabulated on p. 76. Figs. 189 and 191 have been interchanged, and all the references to figures on p. 317 are incorrect. The index at the end of the book is very complete, and includes references to footnotes. The volume will be of permanent value as a book of reference, but must not be regarded as a textbook of optical theory.

T. S.

ABSTRACTS

"Note on the Study of Movements of the Eye." By OTTO GROTRIAN, *Phys. Z.* 18 (1917), 469.

If one endeavours to follow the periphery of a circle, using one eye or both eyes and keeping the head steady, one usually finds that it is easier to do so in one direction rather than the other. The author records the result of such observations by 30 persons. Of these nine found it easier to follow the periphery in the counter-clockwise direction and 19 in the clockwise direction, while the remaining two found both directions equally easy. The author himself made observations on various curves and combinations of curves with straight lines; he always found it was easier to follow a curve in the direction in which the curve was concave towards the left, that is, corresponding to the counter-clockwise direction. He explains the phenomenon as being due to the fact that in any particular case the easier direction will be the one which involves the smaller amount of effort on the part of the muscles of the eye.

Observations were also made on the path followed by one's glance when transferring attention from one point to another. Of 27 persons examined four followed the straight path between the two points; the others followed paths which were curved either upwards or downwards, the line joining the points being horizontal.

J. S. A.

"On the Sensitive Colours which serve for the Detection of Double Refraction." By ALFRED WENZEL, *Phys. Z.* 18 (1917), 472.

On the Young-Helmholtz theory of the three primary sensations of red, green, and blue, König and Dieterici [*Berl. Ber.* (1886), 805; *Z. f. Psych. u. Phys. d. Sinnesorgane* 4 (1892), 241] have shown that each colour in the spectrum can be looked upon as built up of white and a mixed colour or one of the purple colours which are complementary to the spectral greens. This colour can be broken up into the primary sensations contained in it. A colour is therefore characterised by the colour in the spectrum which when added to white would excite the same sensations. For the complete determination of a colour one must take into consideration not only the intensity of the primary sensations, but also the degrees of brightness and saturation of the colour itself.

The author applies equations built up from these considerations to the interference colours obtained in the case of parallel light passing through quartz wedges of angles $1^\circ\ 30'$ and 30° placed in a diagonal position between crossed nicols, and also to the case of cleavage plates of gypsum. The quartz wedges were so cut that the optical axis in the former was parallel, and in the latter perpendicular, to the surface at which the light enters.

The most sensitive colours are always found to appear where the brightest colours of the spectrum are suppressed. For example, in the most sensitive red of the first order both in the gypsum and the quartz cut parallel to the optical axis the light between the Fraunhofer lines *D* and *E* is absent, while in the blue-violet of the second order in the quartz cut perpendicular to the optical axis the light of the *D* lines is absent. The colour

which is most sensitive to small path differences is given by a piece of gypsum 5·6 μ thick placed in a beam of parallel light in a diagonal position between crossed nicols. The interference colour is a purple which is complementary to green of wave-length 540 $\mu\mu$. Almost the same colour can be obtained with quartz 57·5 μ thick and cut parallel to the axis, but in this case it is brighter and less saturated. With quartz cut perpendicular to the axis and of thickness 7·5 mm. the most sensitive colour occurs about 439 $\mu\mu$ in the violet, and is therefore not to be compared with the purple colour as regards sensitiveness to small variations. The difference in the interference colours obtained with quartz cut in the two different directions is caused by the difference in the dispersions of the double refraction and of the coefficients of rotation.

J. S. A.

OBITUARY NOTICE

MATTHEW WILLIAM DUNSCOMBE

It is with great regret that we have to record the death of Mr Matthew William Dunscombe, of St Augustine's Parade, Bristol, on the 6th June, 1918, in his 77th year. There were few who could point to such a long service in the spectacle industry, of which he was an honoured and respected member. He began his apprenticeship to the trade in 1855 with the firm of John Braham, of Bristol, the patentee of the Pantoscopic spectacle; after that, he was for some time in London and York. In 1868 he returned to Bristol to manage the retail business of which in after years he became the principal. Later he came again to London to supervise the optical department of Messrs Cohen, Jacob and Co., of Charterhouse Street, until in 1874 he purchased the Bristol business.

He was the inventor of many forms of spectacles and eye-glasses, some of which became widely known under other names. Notably the "Prima Donna" folder, the pioneer of the class comprising "Perfection" and Canadian patterns.

It was perhaps as a collector of antique spectacle wear that he was best known outside his own immediate circle. He had by care, assiduity, and application of his very special knowledge acquired an unrivalled collection of spectacles and eyeglasses, which was considered valuable and unique enough to be awarded the gold medal of the Victorian Era Exhibition. Unfortunately the whole of this was destroyed by fire when on loan to the Brussels Exhibition some years ago. Nothing daunted he set to and again acquired a collection which soon rivalled the previous one.

He designed an invisible Bifocal lens and was a director of the Kryptok Company in England. He was well known in Masonic Circles. In craft Masonry he was a member of the Beaufort Lodge, Bristol, P.M. of the Tyndale Lodge, Staple Hill, and P.P.G. Supt. Works Province of Gloucestershire. He was P.Z. of the Beaufort Chapter Royal Arch Masons, and P.G. Sword Bearer in the Provincial Grand Chapter, P.M. of the Canynge Lodge of Mark Masons, and a founder, the treasurer of the Dunkerley Lodge of Mark Master Masons, and P.G.S.O. in the Provincial Grand Lodge of Mark Master Masons. He was a Member of the Spectacle Makers' Company and for over 20 years a member of the Council of the British Optical Association. It is in connection with this latter body that his activities in the way of organisation of the Spectacle industry chiefly lay. He was one of the founders of the Association in 1895 and was a keen participator in many of its early fights and struggles for existence. He was President of the Association for two years in succession. Just prior to his death Mr Dunscombe accepted Fellowship of the Optical Society.

He had a kindly, affectionate nature and was much esteemed and respected by all his colleagues to whom it was a regret that the later years of his life should have been clouded by an illness which prevented him from taking his former active participation in optical matters.

J. H. S.